

**TECHNICAL MEMORANDUM**

**for**

**TEST AREA NORTH GROUNDWATER,  
OPERABLE UNIT 1-07B**

**IDAHO NATIONAL ENGINEERING LABORATORY**

**Prepared for**

**U.S. ENVIRONMENTAL PROTECTION AGENCY  
Office of Waste Programs Enforcement  
Washington, D.C. 20460**

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## INTRODUCTION

PRC Environmental Management, Inc. (PRC) has prepared this memorandum to address unresolved issues regarding the September 1993 draft *Feasibility Study for Test Area North Groundwater Operable Unit 1-07B* at the Idaho National Engineering Laboratory (INEL). This memorandum is intended to: (1) reevaluate the hypothesis that dense nonaqueous-phase liquids (DNAPLs) are present in the aquifer as a result of disposal of trichloroethylene (TCE) to the TSF-05 injection well; (2) examine the assumption that 40 pore volumes must be withdrawn as part of the remedial effort, and reanalyze costs if withdrawal of fewer pore volumes is determined to facilitate cleanup; and (3) examine a range of potential preliminary remediation goals. Remediation costs are compared to residual risks as more aggressive cleanup levels are examined; points (2) and (3) are used in this comparison.

The remedial investigation (RI) and feasibility study (FS) hypothesizes that TCE is present as a nonaqueous phase in the groundwater; since TCE is denser than water, this would be a DNAPL. The FS develops remedial alternatives with the assumption that DNAPLs are present, and further states that because secondary DNAPL sources may not be completely removed by any remedial alternative, attainment of remediation goals (maximum contaminant limits [MCLs]) may not be possible.

If there is sufficient uncertainty regarding the presence of the DNAPL phase, then plans to remediate as if there are no DNAPLs present may be the best course of action, with continued monitoring instituted to verify this assumption. If there is no DNAPL phase present, remediation would be less complex, have a higher potential for success, and be less costly.

## HYPOTHESIS OF EXISTENCE OF DNAPL PHASE

The argument that DNAPL is present is based on the assumption that all the TCE used at Test Area North (TAN) was disposed to the injection well (TSF-05); the quantity of TCE used is estimated in the RI as 35,000 gallons (the FS [page 1-14] revises this estimate to approximately 25,670 gallons). According to the mass balance argument in the FS, 572 gallons of TCE is estimated to be present in the groundwater plume, and another 3.1 gallons of TCE was present in the sludge removed from the injection well, leaving the remainder unaccounted for.

There are four issues that corroborate the view that TCE is not present as DNAPL. First, evaporative and other losses would have caused less TCE to be disposed of than was used. Second, mass balances derived from alternative sources of information for this site show that significantly less TCE may have been disposed of to this well than is stated in the FS. Third, it is reported that the TCE disposed of to the well was dissolved in wastewater. Finally, the vertical gradient shows a decreasing TCE concentration with increasing depth at one well cluster downgradient of the injection well. This memorandum examines these issues in greater detail.

Two additional issues should be noted, but will not be discussed further in this memorandum. First, the greatest observed TCE concentrations at this site are near the TSF-05 injection well; the FS takes this as an indication that DNAPLs are present, but other explanations, such as the presence of residual sludge near the well, are likely. Second, DNAPLs have not been found in any monitoring wells or water supply wells. The presence of sludge in the formation, which has been observed, appears to be a likely alternative source at this location.

## **MECHANISMS FOR RELEASE**

The argument that DNAPL is present is based on the assumption that all the TCE used at TAN was disposed of to the injection well (TSF-05); this quantity is estimated to be approximately 25,670 gallons (as pure phase), but this does not account for other losses of TCE, such as volatilization and accidental spillage. TCE has a vapor pressure of 58 millimeters of mercury (mm Hg), which indicates that volatilization will occur readily. According to the Puget Sound Air Pollution Control Agency (PSAPCA 1993), between 5 and 100 percent of TCE used may be lost to the atmosphere through volatilization in a typical industrial setting. Losses may also occur before use if a storage tank or drum leaks, as is common in industrial settings. Spills at the point of use may also account for lost TCE.

This memorandum assumes that 5 percent of all TCE was lost through volatilization; no assumptions regarding other losses are made. Losses may have been significantly larger, but 5 percent represents a conservative assumption.

## **ALTERNATIVE SOURCES OF INFORMATION REGARDING TCE USE AND MASS BALANCES**

Another source of information regarding TCE use and disposal at this site is the Resource Conservation and Recovery Act (RCRA) facility investigation (RFI) for the TAN groundwater, dated 1988 (EG&G 1988). This source identifies volumes of hazardous components disposed of to the TSF-05 injection well, as follow:

- TAN-604, maintenance shop: 5 gallons per year from 1956 to 1972
- TAN-607, chemical cleaning room: 4,492 gallons per year from 1955 to 1972
- TAN-607, photo lab/cold preparation lab: "small quantities," 1955 to 1972

The materials used in the chemical cleaning room (also referred to as the pipe laundry) were primarily acids and caustics, and did not involve large quantities of TCE. The phrase "small quantities" is interpreted to mean less than 5 gallons per year. According to EG&G (1988), waste generated in the decontamination room (identified in the FS as a source of TCE to the injection well) was disposed of to the TSF intermediate-level waste disposal system rather than to the TSF-05 injection well.

The quantity of TCE disposed of is not more precisely specified, although ignitable waste is assumed to be partly TCE, while corrosive wastewater is assumed to not include TCE. The total waste disposed of to the TSF-05 injection well is summarized by EG&G (1988, page 25) with a total of 85 gallons of ignitable wastes estimated to have been disposed between 1955 to 1972. This averages out to 5 gallons per year over 17 years, or the quantity disposed of from the maintenance shop alone. If an additional 5 gallons per year is assumed from the photo lab/cold preparation lab, this amounts to a total of 170 gallons. Since this is ignitable waste, it includes *all* ignitable wastes; these are typically solvents, of which TCE is only one. Therefore, assuming that all ignitable waste is TCE, 170 gallons is a conservative estimate.

This list does not include a vapor degreaser used in the chemical cleaning room that is also described by EG&G (1988). This vapor degreaser used TCE and had a capacity of 1,500 gallons. Since its period of operation is described as the "early 1970s" (EG&G 1988), it is assumed that it operated from 1970 to late 1972, after which wastewater was disposed of to the TAN disposal pond. This is the only process that is directly described as using TCE (EG&G 1988).

Another document (Allied 1971) describes TCE use in 1970 as totaling 370 gallons. If three assumptions are made, the TCE use may be alternatively estimated. First, use during 1970 to 1972 is assumed as 370 gallons per year, which totals 1,100 gallons. Second, other sources are assumed to contribute 170 gallons over the entire 17 years. The sum of these two amounts is 1,270 gallons. Third, 5 percent volatilization is assumed, which yields a total of 1,206.5 gallons of disposed TCE.

In addition to document reviews, knowledgeable persons were interviewed. One such source of information is Mr. Michael Navetta, P.E.<sup>1</sup>, who provided RCRA support at the chemical plant from 1989 to 1991; he wrote RCRA permits for the facilities that generated waste disposed of at the injection well. According to Mr. Navetta (1993), at most about 1 to 10 million gallons of TCE-contaminated wastewater was disposed of to this injection well every year. Based on his knowledge of this site, Mr. Navetta estimates that this wastewater contained 10 to 15 parts per million (ppm) TCE. At these concentrations, TCE would be expected to be dissolved as an aqueous phase rather than as a separate nonaqueous phase. Equation (1) relates this concentration in ppm (or milligrams per liter [mg/L]) to gallon per year, and includes the conservative assumption that 10 million gallons per year were disposed. The density of TCE is 1,460 kilograms per cubic meter (kg/m<sup>3</sup>).

$$15 \frac{\text{mg}}{\text{L}} \times \frac{\text{m}^3}{264 \text{ gal}} \times 10^3 \frac{\text{L}}{\text{m}^3} \times 10^7 \frac{\text{gal}}{\text{year}} \times \frac{\text{kg}}{10^6 \text{ mg}} \times \frac{\text{m}^3}{1460 \text{ kg}} \times 264 \frac{\text{gal}}{\text{m}^3} = 103 \text{ gallons per year} \quad (1)$$

Assuming 19 years of disposal, 1,960 gallons of TCE (aqueous phase) would have been disposed of at the TSF-05 injection well. According to the information received, this is a conservative estimate. If one million gallons of wastewater per year at 10 ppm TCE was disposed of, then only 131 gallons were disposed of over 19 years. However, this is less than the estimated 572 gallons of TCE as dissolved phase currently in the aquifer. Based on Mr. Navetta's information, 575.1 gallons in the groundwater and sludge represents between 29 and 100 percent of the TCE that was disposed. Using only the information in the Allied (1971) and the EG&G (1988) documents, this 575.1 gallons is 47.7 percent of the total amount disposed of.

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<sup>1</sup>Mr. Navetta is a registered professional engineer with 14 years' experience at RCRA and CERCLA sites. He has a B.S. in chemical engineering.

## **DISSOLVED FOR DISPOSAL**

Sufficient wastewater was disposed of with the TCE to the injection well to solubilize it. The quantity of wastewater disposed of per year, however, is not described with certainty, although the disposal pond, which replaced the TSF-05 injection well, was designed to accommodate up to  $33 \times 10^6$  gallons per year (EG&G 1988). This design accounted for evaporation. If the TSF-05 injection well was designed to accommodate one-tenth of this flow ( $3.3 \times 10^6$  gallons per year), which is consistent with Mr. Navetta's estimate, the previously assumed maximum amount disposed of per year ( $380 \times 0.95 = 361$  gallons), the resulting concentration is about 170 mg/L, or about 17 percent of the solubility limit. The concentration is further reduced because of convective transport in groundwater.

The solubility limit for TCE in water is 1,000 mg/L (NIOSH 1990). One percent of 1,000 mg/L is 10 mg/L or 10,000  $\mu\text{g/L}$ . The maximum observed TCE concentrations are only about 10,000 to 20,000  $\mu\text{g/L}$ . These levels are observed in samples collected from the injection well, but only in samples collected before removal of the sludge from the well in January 1990. Only one well since then has shown concentrations greater than one percent of the solubility limit; this is well TAN-25, which showed a concentration of 17,000  $\mu\text{g/L}$  in June 1993. This well is only 25 feet from the TSF-05 injection well. Samples from all other wells, including TSF-05, have not shown concentrations greater than 10,000  $\mu\text{g/L}$  since January 1990. According to EPA guidance (1992a), concentrations of greater than 1 percent of the solubility limit indicate that DNAPLs may be present. The single well showing sufficient concentrations to indicate DNAPLs is likely influenced by TCE-contaminated sludge remaining in the basalt aquifer close to the injection well. Concentrations at the TSF-05 well have diminished since January 1990, indicating that sludge removal from the injection well reduced the source of TCE for groundwater.

## **ANALYSIS OF VERTICAL CONCENTRATION GRADIENT**

An analysis of the observed vertical concentration gradient shows a decrease in concentrations with increasing depth. Monitoring well USGS-24 is approximately 1,000 feet downgradient of the injection well and is screened at 255 to 265 feet, 270 to 275 feet, and 285 to 325 feet. Monitoring well TAN-19 is adjacent to USGS-24, and is screened just above the Q-R interbed at 396 to 416 feet below ground surface (bgs). These are the nearest cluster wells to the TSF-05 injection well. FY-92 Phase II sampling results for TCE found between 880 and 1,400  $\mu\text{g/L}$  in USGS-24, and between 83 and 94  $\mu\text{g/L}$  in TAN-19. This represents about one order of magnitude difference,

and shows a decreasing concentration with depth. The opposite concentration gradient (increasing with depth) would be indicative of DNAPLs; the observed gradient, however, indicates a source higher up. Sludge remaining in the upper portion of the aquifer likely accounts for this observed concentration gradient; the TSF-05 injection well is screened from 180 to 244 feet bgs and from 269 to 305 feet bgs. Sludge is expected to be present in the same range as the screened intervals, which match the screened intervals of USGS-24. One of the criteria in EPA's guidance (1992a) for demonstrating the potential presence of DNAPLs is that concentrations increase with depth. Since the opposite condition exists, this suggests that DNAPLs are not present.

## **ENGINEERING ASSUMPTIONS/REANALYSIS OF COST**

### **FORTY PORE VOLUMES ASSUMPTION**

The engineering assumption that most significantly affected the cost analysis in the FS was the assumption that 40 pore volumes of groundwater need to be withdrawn from the defined groundwater plume in order to effect remediation. This appears to be based on the assumption that a separate DNAPL phase is present, which leads to a further assumption that groundwater must be pumped and treated for 30 years.

This memorandum presents a reanalysis of cost that assumes that there is no separate DNAPL phase, and hence that only five pore volumes must be withdrawn. Modeling efforts described in the RI assume that no retardation occurs, which means that  $K_d$  was assumed to equal zero. Under this assumption, technically only one pore volume would need to be removed to remediate this site. However, to be conservative, five pore volumes are assumed to be required; this is significantly less conservative than the assumption that 40 pore volumes must be withdrawn, but is still assumed to be sufficiently conservative. The number of years to pump one pore volume is 0.8 for the largest groundwater plume (from Appendix A). This leads to the assumption that groundwater will be pumped and treated for only 4 years. Although 4 years is used for estimating cost for all scenarios, this is overly conservative for smaller groundwater plumes.

In addition, the 5,000- $\mu\text{g/L}$  capture zone has a calculated removal time of 37 days for one pore volume in the FS (Appendix B). Even at 40 pore volumes, the estimated time for cleanup is 1,480 days or just over 4 years. Hence, the 30-year operating time assumption in the FS results in a significant overestimate of costs based on removal times shown.

This reanalysis assumes that operations to remove groundwater will begin in 1996, and continue for 4 years. No variation in time is assumed for different capture zones. A five percent discount rate is assumed. Monitoring for the 47 years is still assumed. Costs are presented for year zero (1994). Other assumptions are identical to those used in the FS.

Variable target groundwater cleanup levels were assumed, including: 12,500 parts per billion (ppb) (the assumed groundwater concentration if only residual sludge in the formation is removed); 5,000 ppb; 1,250 ppb; 1,000 ppb; 500 ppb; 125 ppb; 25 ppb; and 5 ppb. The 12,500 ppb concentration was assumed because it is an order of magnitude higher than 1,250 ppb, which makes the process of estimating dilution times easier. The FS modeled the change in concentration to the year 2044 for removal of the 5,000-ppb, 1,000-ppb, 500-ppb, and 50-ppb plumes. However, the cost analysis for only the 25-ppb and 5,000-ppb plumes were evaluated in the FS. Costs for the 12,500-ppb plume were assumed to be the same as those calculated in the FS for alternative 4, assuming that the enhanced pump-and-treat system operates for 2 years (Figure 4-1, page 4-40). Costs for the remaining target groundwater cleanup levels were estimated independently, assuming that only five pore volumes must be withdrawn. Figure 1 (in Appendix A) shows the costs for various treatment options.

If more or fewer pore volumes must be withdrawn, then operations and maintenance costs will rise or fall accordingly in proportion for all capture zones. However, this reflects the conservative assumption that 4 years is required to remove all capture zones. In actuality, if a smaller (higher groundwater target concentration) aquifer volume requires remediation, the number of years required to pump should decrease. Hence O&M costs may be overestimated for the smaller groundwater plume withdrawal (e.g., 5,000 µg/L plume removal).

The figures in Appendix A include the following:

- Figure 1 shows the increase in cost with decreasing target groundwater clean up levels.
- Figure 2 shows the residential risk immediately following cleanup of various groundwater plumes. This year is assumed to be 1998.
- Figure 3 shows the residential risk 50 years from now (2044) for various plume removal options. This period was chosen to maintain consistency with the FS. Maximum future concentrations, as shown in Table A-1 of the FS, are used; if necessary, future concentrations were estimated based on information in this table and in Figure A-8.



- Figure 4 shows the cost of clean up for various options versus the time required following clean up to attain a level of 125 µg/L.
- Figure 5 shows the difference in cost for the time gained of various groundwater removal options. This figure is explained in the next section.

### PRELIMINARY REMEDIATION GOALS (PRGS)

As indicated in the FS, a remedial action objective for the larger dissolved TCE plume is to restore groundwater in the plume to contaminant concentrations that would result in an excess lifetime cancer risk within the acceptable risk range of  $10^{-4}$  to  $10^{-6}$ . Chemical-specific ARARs should be identified and considered to be PRGs as an initial step. However, meeting the MCL for TCE (5 µg/L) in groundwater is likely to be both costly and ineffective given the available cleanup technologies for fractured basalt (especially for large dilute plumes). Therefore, a less conservative cleanup goal may be acceptable to all parties. While this memorandum does not attempt to resolve this issue, it does present a cost/benefit analysis.

Table 2 shows the variation in excess lifetime cancer risk and the hazard index for TCE exposure for various groundwater concentrations. The risks and hazard indexes shown in this table are based on EPA (1992b) guidance, and assume that a residential exposure occurs. Carcinogenic risks related to TCE calculated in the RI baseline risk assessment were about three times lower.

**TABLE 2**  
**TCE RISKS AND HAZARD INDEXES FOR VARIABLE CONCENTRATIONS**

Concentration (ppb)	Excess Lifetime Cancer Risk	Hazard Index
12,500	$5 \times 10^{-3}$	51.2
5,000	$2 \times 10^{-3}$	20.6
1,250	$5 \times 10^{-4}$	4.1
125	$5 \times 10^{-5}$	0.52
25	$1 \times 10^{-5}$	0.10
5	$2 \times 10^{-6}$	0.02

To convert from the residential to the occupational cancer risk, the risk is multiplied by 0.291. This factor was obtained by adjusting from residential to occupational standard default assumptions presented in EPA (1991) guidance.

Figure 2 shows how risk decreases with decreasing target cleanup levels. These groundwater concentrations are those anticipated immediately following clean up, if one assumes a residential scenario of groundwater drawn directly from the most contaminated part of the aquifer. The risks are shown for a residential scenario for comparison. This is not a realistic scenario; the current water source at this site shows concentrations below the MCL of 5 µg/L. This current source is likely to both remain below MCLs and continue to be used as the water source at this location.

After clean up, groundwater concentrations will drop. By the year 2044, these reductions would be significant, as shown in the FS in Table A-1 and in Figure A-8. The year 2044 represents the time for which the future residential scenario was evaluated in the FS. Figure 3 shows the risks calculated for 2044. It can be seen that there are no anticipated risks above the  $10^{-4}$  to  $10^{-6}$  excess lifetime cancer risk range, even if only sludge remaining in the basalt is removed. This removal results in a predicted maximum groundwater concentration of 72 ppb, yielding a carcinogenic risk of about  $3 \times 10^{-5}$  and a hazard index of 0.3 in the year 2044. It should be noted that, assuming a constant source at the TSF-05 injection well for the last 20 to 30 years, observed TCE concentrations and areal distribution downgradient from the injection well are significantly smaller than predicted by the groundwater model. Therefore, actual groundwater concentrations in the future may be significantly lower than predicted by the groundwater model.

Figure 4 shows the cost of various groundwater removal options in relation to the time required to reach the 125-µg/L concentration. The drop in concentration is approximated from data in Figure A-8; an exponential drop is assumed to fill in data that are not apparent from this figure. The cleanup time to 125 µg/L was chosen because the time to reach this concentration can be estimated from information shown in Figure A-8 in the FS; 125 µg/L is also within the  $10^{-4}$  to  $10^{-6}$  target risk range for TCE. This figure shows that the cost of clean up increases rapidly from sludge removal only to removal of the 5,000-ppb groundwater plume, with relatively little improvement in the time required to reach the 125-µg/L concentration. Remediation of the less contaminated groundwater plume shows a relatively smaller increase in cost relative to the improvement in the time saved to reach 125 µg/L.

What is the cost of additional years of use? Additional years of use are calculated as the time required to attain maximum beneficial use (5 µg/L) minus the time required if only remaining sludges in the basalts are removed. These years are approximated using the times for concentrations to drop shown in Figure A-8 of the FS. The cost for these additional years is the difference in cost for these two cleanup levels (sludge cleanup only versus removal of a given groundwater concentration plume). For example, the cost for sludge removal only is about \$13 million; groundwater cleanup to 500 µg/L costs about \$39 million. The difference is \$26 million, for a cost of about \$1 million per year to gain about 25 years' additional use. This must be balanced against the likelihood that residential use will occur before the acceptable risk range is attained. This type of cost-benefit analysis is shown in Figure 5. This figure shows the years of groundwater use gained versus the cost. The time to clean up to the 5-µg/L level is assumed. Both of these parameters (years and cost) are measured over a baseline condition of sludge removal only; if sludge removal only were placed on this figure, then the plotted line would pass through the origin.

### SUMMARY/CONCLUSIONS

Several points have been made in this technical memorandum. First, the quantities stated are based on use, not disposal; some TCE was lost to processes other than disposal. Second, alternative sources of information indicate that much less TCE was probably disposed of to this well than the FS indicates. Third, the volume of wastewater disposed of at the TSF-05 injection well was sufficient to solubilize the TCE disposed. Fourth, the vertical gradient of TCE contamination indicates that the sludge remaining in the upper portion of the aquifer is the likely residual source, not a separate DNAPL phase, as the FS suggests. In addition, DNAPLs have never been observed in any monitoring wells.

These points indicate that it is unlikely that TCE is present in the aquifer as a DNAPL. The FS assumes that 40 pore volumes must be withdrawn to remove the groundwater plume. This is based on the assumption that a separate DNAPL phase is present. The problem with assuming that 40 pore volumes must be withdrawn is that operation and maintenance costs may be grossly overestimated. In addition, an analysis of risk shows that removal of sludge in the formation only, combined with modeled results of the passage of 50 years' time, results in a residential risk of less than  $10^{-4}$ . Other methods, such as institutional controls, could be used to prevent groundwater use until monitoring indicates that acceptable use levels have been reached.

Analysis of a phased remedial approach in the FS is recommended. This type of approach would use the existing interim action system to evaluate the effectiveness of further remediation. Further evidence and analysis may demonstrate that upgrading and adding wells to address aqueous TCE is practical and will allow the PRGs to be achieved more quickly.

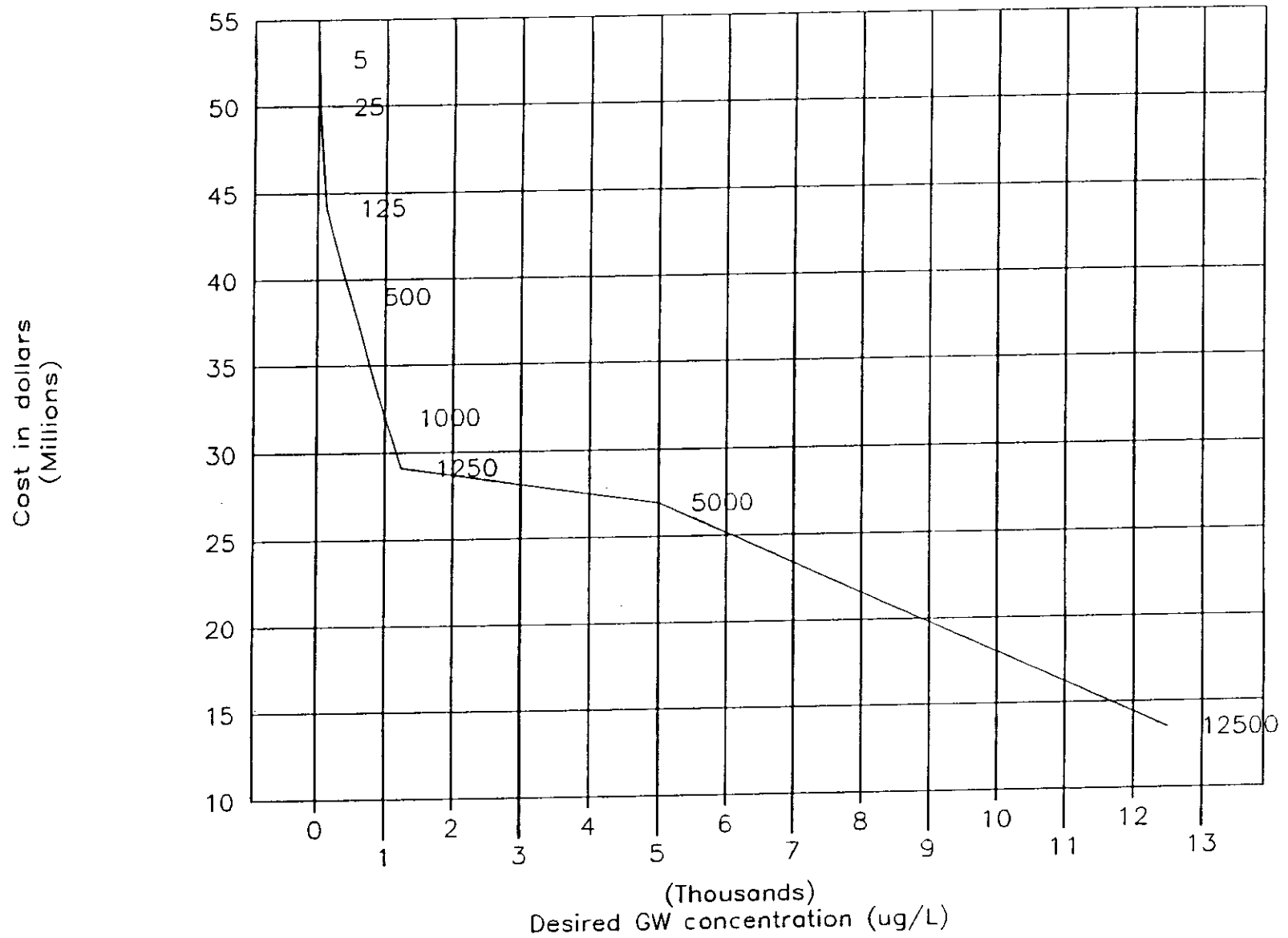
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**APPENDIX A**  
**FIGURES 1 THROUGH 5**

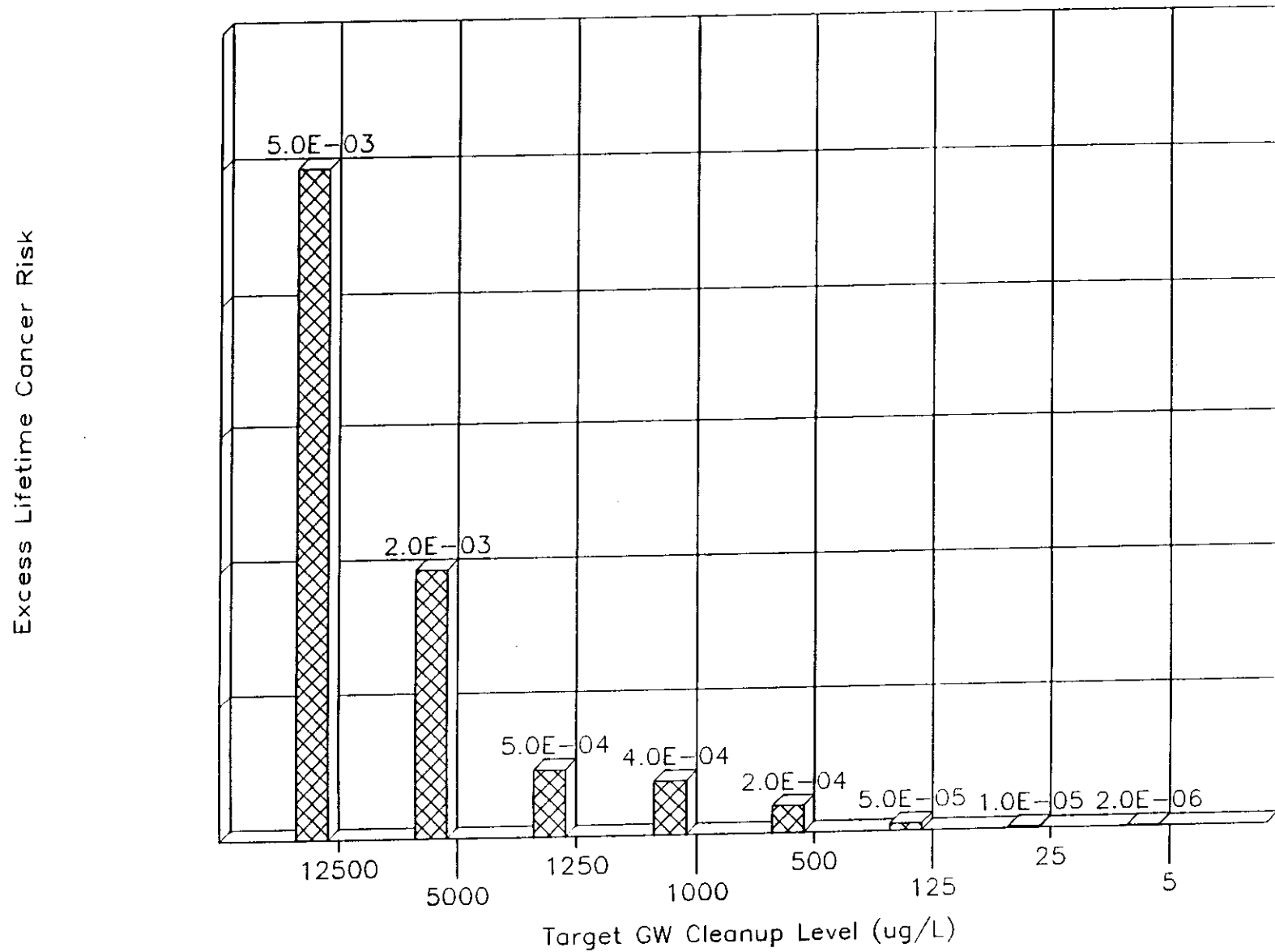
# Figure 1

Cleanup Costs



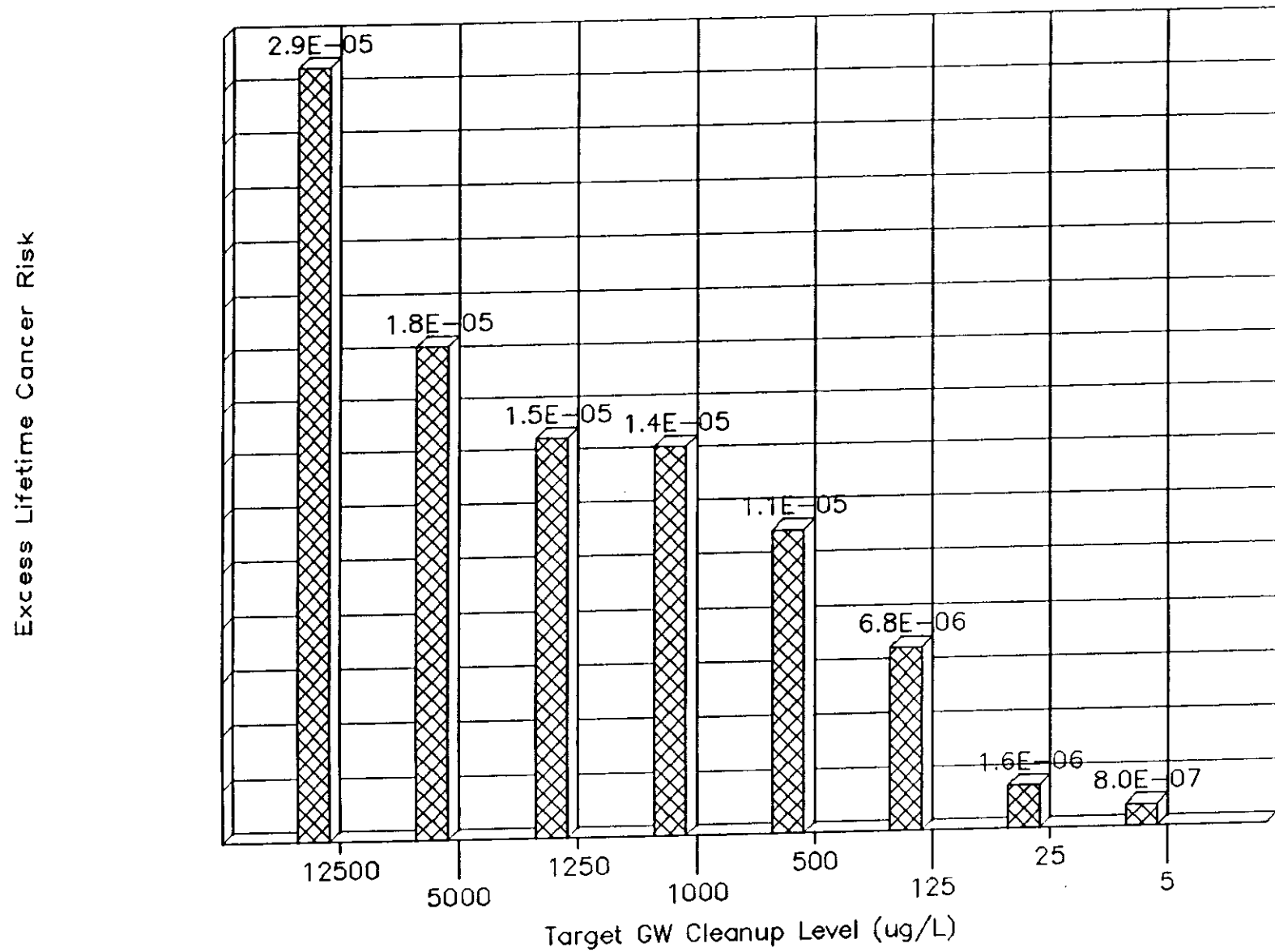
# Figure 2

Residential risk after cleanup (1998)



# Figure 3

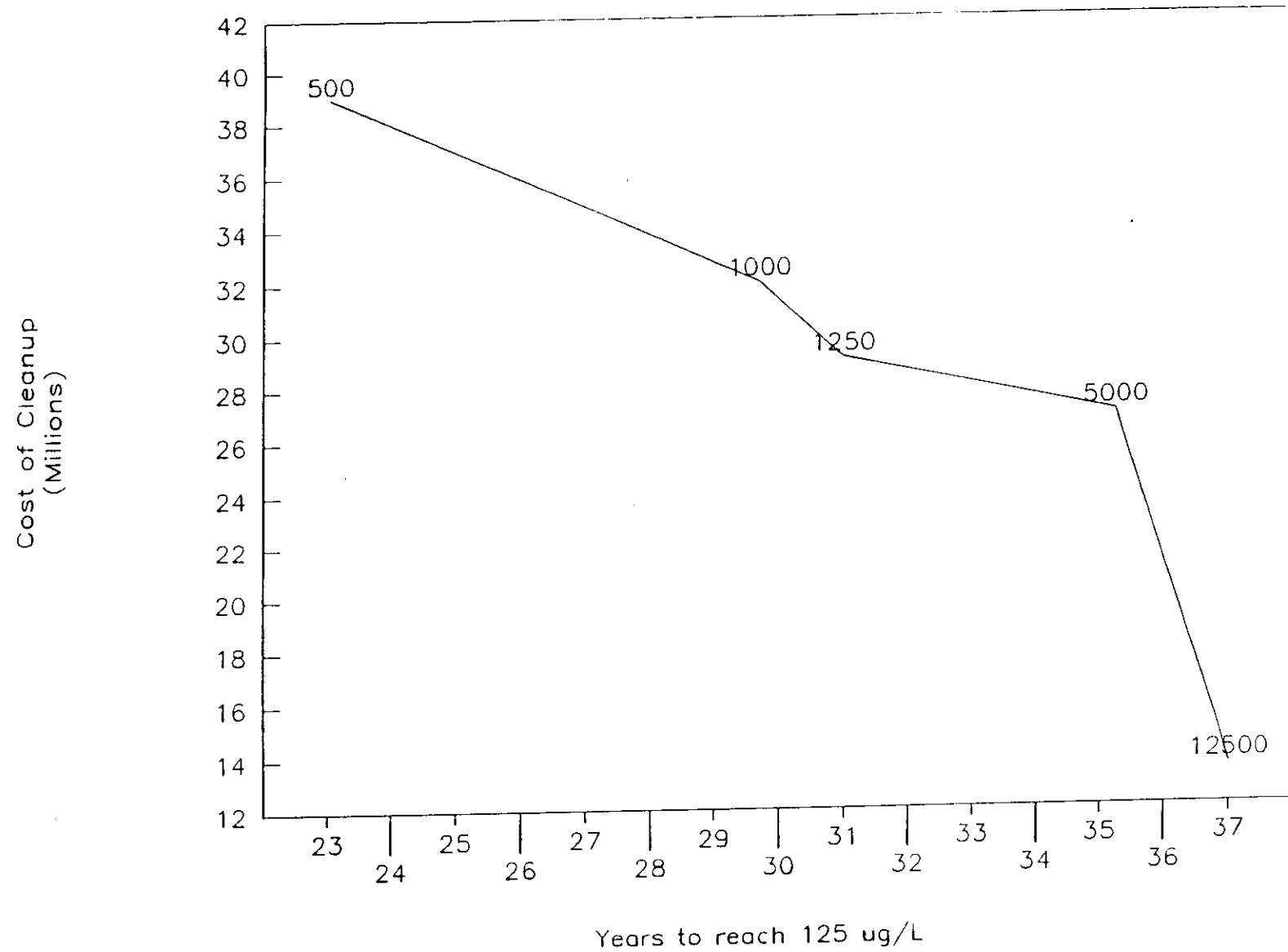
Residential risk after 50 years (2044)





# Figure 4

Cost vs. Time after Remediation



# Figure 5

Cost Benefit Analysis

